RACE CAR SEMI-ACTIVE SUSPENSION CONTROL SYSTEM

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"I declare this report is on my own work except for summary and quotes that I have mentioned its sources"

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To my beloved family especially my mother, Rabiah binti Abdul Rahman and my father, Omar bin Abdullah

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In the name of Allah, the most Gracious and most Merciful

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ABSTRACT

Suspension system is the connector between the tire and the body of a vehicle. In addition, the suspension also affects the performance and stability of a vehicle, especially on racing cars. Therefore, to provide recommendations to the racing car, this suspension system has been studied in detail in this report. Two types of suspension systems studied were passive and semi-active systems. The passive system is the system that has been used in almost vehicle nowdays To analyse these two types of suspension systems, parameter from *Subaru Impreza Group N Rally Car* racing car has been taken. Both suspension systems will be studied through simulation in MATLAB Simulink and was analyzed and validate with CarSimEd software. Through these models, the equation of motion has been drafted by a quarter car, half car and fullcar model. Through this equation of motion, the blocks will be made in the MATLAB Simulink and the suspension system will be analysed.

ABSTRAK

Sistem suspensi adalah penyambung diantara tayar dan badan sesebuah kenderaan. Selain daripada itu, sistem suspensi juga memberi kesan kepada kecekapan dan kestabilan sesebuah kenderaan terutamanya kepada kereta lumba. Oleh kerana itu, bagi memberi saranan kepada sesuatu kereta lumba, sistem suspensi ini telah dikaji secara terperinci di dalam laporan ini. Dua jenis suspensi yang dikaji adalah sistem pasif dan juga sistem separuh aktif. Sistem pasif adalah sistem suspensi yang telah digunakan di dalam kebanyakan kereta sekarang. Untuk menganalisis dua jenis sistem suspensi ini, pembolehubah daripada kereta lumba *Subaru Impreza Group N Rally Car* telah diambil. Kedua-dua sistem suspensi ini akan dikaji melalui simulasi di dalam perisian MATLAB Simulink dan dianalisis dan disahkan melalui perisian CarSimEd. Melalui model kenderaan ini, persamaan pergerakan telah dirangka melalui suku kereta, separuh kereta dan juga sepenuh kereta. Melalui persamaan pergerakan inilah, blok-blok akan dibuat di dalam MATLAB Simulink dan melalui MATLAB Simulink sistem suspensi akan dianalisis.

TABLE OF CONTENT

CHAPTER	TOPIC	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	TABLE OF CONTENTS	vii
	LIST OF FIGURE	xi
	LIST OF TABLE	xiv
	LIST OF SYMBOLS AND ABBREVIATIONS	xix
CHAPTER 1	**INTRODUCTION**	
	1.1 Overview	1
	1.2 Objective	4
	1.3 Scope	4
	1.4 Problem Statement	5
	1.5 Project Gantt Chart	6
	1.6 Project Outline	8

CHAPTER	TOPIC	PAGE

CHAPTER 2 LITERATURE REVIEW

2.1 Background Of The Suspension System 9
2.2 Conventional Suspension System 11
2.3 Advances Suspension System 12
2.3.1 Semi active suspension system 12
2.3.2 Full Active Suspension System 14
2.4 Comparison Between Racing Car And Passenger Car Suspension 16
2.5 PID Controller 17
2.5.1 Tuning of PID controller 18
2.6 Skyhook Controller 18
2.7 Previous Study on Technical Paper 20
2.7.1 Simulation 22
2.7.2 Expected Result 24

CHAPTER 3 METHODOLOGY 25

3.1 Modelling Assumptions 26
3.2 Project Flow Chart 27
3.3 Proposed Project Methodology 28
3.4 Vehicle Suspension Control 29

CHAPTER	TOPIC	PAGE

3.5 Vehicle Data Setup For Subaru Impreza Group N Rally Car 29

3.5.1 Position of the Centre of Gravity 31

3.6 The Description Of Model Disturbance 33

3.7 Chassis Dynamic In Vertical Motion 35

3.7.1 Vehicle Ride Model 35

3.7.2 Full Car Passive Suspension 36

3.7.3 Full Car Semi Active Suspension 43

3.7.3.1 Decoupling Transformation 46

3.8 MATLAB SIMULATION 48

3.8.1 Ride Model simulink 49

3.8.2 Validation of 7 DOF ride model using CarSimEd 50

3.9 Data analysis 56

3.10 Controller Design 57

3.10.1 Controller tuning 57

3.10.2 Sensitivity of PID 59

CHAPTER 4 RESULT AND DISCUSSION 60

4.1 Validation of 7 DOF ride model using CarSimEd 60

4.2 Values Of Controllers 62

CHAPTER	TOPIC	PAGE

4.2.1 Body Displacement 63

4.2.2 Pitch Angle 65

4.2.3 Roll Angle 67

4.3 Sprung Mass Result 69

4.3.1 Body Displacement, Pitch Angle and Roll Angle 69

4.3.2 Body Acceleration, Pitch acceleration and Roll acceleration

4.4 Unsprung Mass Result 73

4.4.1 Suspension Deflection 73

4.4.2 Tire Load 76

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

5.2 Recommendation

REFERENCES 81

APPENDICES 84

LIST OF FIGURES

NO.	TITLE	PAGE
Figure 2.1	Quarter Car Model Suspension System	10
Figure 2.2	Passive Suspension system	11
Figure 2.3	Semi-active suspension system	13
Figure 2.4	Active suspension system	14
Figure 2.5	(a) Low-bandwidth active suspension system (b) High-bandwidth active suspension system	15
Figure 2.6	Basic Controller Design	17
Figure 2.7	The block diagram of the PID controller	17
Figure 2.8	Two-sensor based Skyhook control.	19
Figure 2.9	Skyhook ideal configuration	20
Figure 2.10	Bumpy road, suspensiontravel limits = ± 8cm	23
Figure 2.11	Spool valve displacement = ±1 cm Actual bumpy road input	23
Figure 2.12	sprung mass Vs time (bumpy road)	24
Figure 2.13	sprung mass acceleration Vs time (bumpy road)	24
Figure 2.14	suspension travel Vs time (bumpy road)	25
Figure 2.15	Tyre deflection Vs time (bumply road)	25
Figure 3.1	Summary process flow for PSM 1 and PSM 2	29
Figure 3.2	Project methodology flowchart	30
Figure 3.3	Vehicle suspension control	31
Figure 3.4	Subaru Impreza specification	32
Figure 3.5	Static loads on level ground	33

Figure 3.6	The dimension of road bump	35
Figure 3.7	The signal builder presents in Matlab-Simulink view	35
Figure 3.8	full car model	37
Figure 3.9	Free Body Diagram For Full Car	37
Figure 3.10	pitch/no rolling	38
Figure 3.11	roll/no pitching	39
Figure 3.12	pitch/ no rolling	40
Figure 3.13	roll/no pitching	41
Figure 3.14	Full Car Model	45
Figure 3.15	Free Body Diagram For Full Car	45
Figure 3.16	Free body diagram for full car model	48
Figure 3.17	The Matlab R2009b	50
Figure 3.18	The simulink library browser and the layer	50
Figure 3.19	The Modelling Of 7DOF Ride Model	51
Figure 3.20	Vehicle body parameters	52
Figure 3.21	suspension parameters	53
Figure 3.22	tire parameter	53
Figure 3.23	big bumps input for ride over bump test	54
Figure 3.24	CarSimEd run setup	54
Figure 3.25	the modelling to validate	55
Figure 3.26	graph of body acceleration versus time	56
Figure 3.27	Graph of pitch acceleration versus time	56
Figure 3.28	the position of PID and skyhook controller	58
Figure 3.29	the PID controller	59
Figure 3.30	PID tuner	59

Figure 4.1	vehicle body acceleration vs time	61
Figure 4.2	pitch acceleration vs time	61
Figure 4.3	body displacement vs time	69
Figure 4.4	body displacement vs time	69

Figure 4.5	pitch angle vs time	70
Figure 4.6	roll angle vs time	70
Figure 4.7	body acceleration vs time	71
Figure 4.8	pitch acceleration vs time	72
Figure 4.9	roll acceleration vs time	72
Figure 4.10	Front left suspension deflection vs time	73
Figure 4.11	Rear left suspension deflection vs time	74
Figure 4.12	Front right suspension deflection vs time	75
Figure 4.13	Rear right suspension deflection vs time	75
Figure 4.14	Front left tire load	76
Figure 4.15	Rear left tyre load	76
Figure 4.16	Front right tyre load	77
Figure 4.17	Rear right tyre load	77

LIST OF TABLES

NO.	TITLE	PAGE
Table 1.1	PSM 1 Gantt Chart	6
Table 1.2	PSM 2 Gantt Chart	7
Table 2.1	Zeigler-Nichols tuning rules	18
Table 2.2	Parameters for active suspension	21
Table 2.3	Zeigler- Nichols tuning rules	22
Table 2.4	Reduction in peak values different parameters (bumpy road)	26
Table 3.1	Exterior Dimension	32
Table 3.2	Vehicle Specification of Subaru Impreza	32
Table 3.3	Vehicle Data measurement	34
Table 3.4	degree of freedom for vehicle ride model	36
Table 3.5	Parameter in 7 DOF validate	55
Table 3.6	The parameter of *Subaru Impreza Group N Rally Car*	
Table 4.1	PID and skyhook values after tuning	62
Table 4.2	Proportional (P) and errors values	63
Table 4.3	Integral (I) and errors values	63
Table 4.4	Derivative (D) and errors values	64
Table 4.5	Proportional (P) and errors values	65

Table 4.6	Integral (I) and errors values	65
Table 4.7	Derivative (D) and errors values	66
Table 4.8	Proportional (P) and errors values	67
Table 4.9	Integral (I) and errors values	67
Table 4.10	Derivative (D) and errors values	68
Table 4.11	The new values of PID and skyhook controllers	68
Table 4.12	Reduction in peak values	71
Table 4.13	Reduction in peak values	73
Table 4.14	Reduction in peak values	78

LIST OF SYMBOLS AND ABBREVIATIONS

DOF	= degree of freedoms
COG	= center of gravity
Ms	= mass body
Mu	= mass unsprung
g	= gravity force
K	= spring
C	= damper
Kt	= tyre spring
Zs	= sprung mass displacement at body centre of gravity
Zu	= unsprung mass displacement at body centre of gravity
Zr	= road displacement
PID	= Proportional Integral Derivative
e	= errors values
Kp	= proportional gain
Ti	= integral time
Td	= Derivative time
F_{sky}	= skyhook actuator force
B_{sky}	= skyhook constant value
C_{sky}	= skyhook damping control signal
Z_r	= road input disturbance
F_{z1}	= front vertical force
F_{z2}	= rear vertical force
F_{fl}	= suspension force at front left corner
F_{fr}	= suspension force at front right corner
F_{rl}	= suspension force at rear left corner
F_{rr}	= suspension force at rear right corner

$\ddot{z}_s$	= sprung mass acceleration at body centre of gravity
$F_{pfl};F_{pfr};$ $F_{prl};F_{prr}$	= pneumatic actuator forces at front left, front right, rear left and rear right corners,
K_{sfl}	= front left suspension spring stiffness
K_{sfr}	= front right suspension spring stiffness
K_{srr}	= rear right suspension spring stiffness
K_{srl}	= rear left suspension spring stiffness
C_{sfr}	= front right suspension damping
C_{sfl}	= front left suspension damping
C_{srr}	= rear right suspension damping
C_{srl}	= rear left suspension damping
z_{brl}	= rear left sprung mass
z_{brr}	= rear right sprung mass
z_{bfr}	= front right sprung mass
z_{bff}	= front right sorung mass
$Z_{u,fr}$	= front right unsprung masses displacement
$Z_{u,fl}$	= front left unsprung masses displacement
$Z_{u,rr}$	= rear right unsprung masses displacement
$Z_{u,rl}$	= rear left unsprung masses displacement
$\dot{Z}_{u,fr}$	= front right unsprung masses velocity
$\dot{Z}_{u,fl}$	= front left unsprung masses velocity
$\dot{Z}_{u,rr}$	= rear right unsprung masses velocity
$\dot{Z}_{u,rl}$	= rear left unsprung masses velocity
a	= distance between front of vehicle and C.G. of sprung mass
b	= distance between rear of vehicle and C.G. of sprung mass
w @ t	= wheelbase
θ	= pitch angle at body centre of gravity
φ	= roll angle at body centre of gravity
$Z_{s,fl}$	= front left sprung mass displacement

$Z_{s,fr}$ = front right sprung mass displacement

$Z_{s,rl}$ = rear left sprung mass displacement

$Z_{s,rr}$ = rear right sprung mass displacement

LIST OF APPENDICES

	TITLE	PAGE
Appendix A	7 DOF Passive subsystem	84
Appendix B	Passive sprung mass subsystem	85
Appendix C	Fsfl subsystem	86
Appendix D	Fdfl susbsystem	86
Appendix E	Fsrl subsystem	86
Appendix F	Fdrl subsystem	86
Appendix G	Pitch subsystem	87
Appendix H	Roll subsystem	88
Appendix I	Unsprung front left subsystem	89
Appendix J	Unsprung front right subsystem	89
Appendix K	Semi-active subsystem	90
Appendix L	Skyhook subsystem	91
Appendix M	Decoupling transformation subsystem	91

CHAPTER 1

INTRODUCTION

This chapter will introduce the reason and aims of this project. The reason and aims will be represent in this chapter by objectives, scope and problem statement.

1.1 BACKGROUND

One of the most important systems in the vehicle is chassis system. Chassis are all vehicle structures except body and engine. The chassis components are chassis beam, steering system, braking system, suspension system, tire and wheel and driveline.

This report is focus in the suspension system. Based on Duffy, James E (2009), the suspension system allows a vehicle's tires and wheels to move up and down over bumps and holes in the road. It makes the vehicle ride more smoothly over rough roads. The suspension system consists of a series of arms, rods, ball joint, bushings and other part. The suspension system works in unison with the tires, unibody or frame, wheels, wheels bearings, brake system, and steering system to provide a safe and comfortable means of transportation.

The comfortable is one of important elements in designing a car suspension system. A function of the suspension is to minimize the car body vibration caused by road surface, to support the vehicle body and keeping the vehicle occupant in comfortable and for vehicle handling. The suspension system for ground vehicle is located between the vehicle body and the vehicle wheels.

All the systems in vehicle have the own functions including the suspension system. One from the function is to supports the weight of the frame, body, engine, transmission, drive train and passengers. For the passengers, the suspension system will provides a smooth, comfortable ride by allowing the wheels and tires to move up and down with minimum movement of the vehicle. Sometimes, the vehicle will become the body roll when the rapid cornering. Body roll is a vehicle leans to one side. The suspension system will allows rapid cornering without extreme body roll.

The suspension systems is keeps the tires in firm contact with the road, even after striking bumps or holes in the roads. When accelerating or heavily load, suspension system will prevent excessive body squat. Body squat is body tilts down in rear. Its also can prevents excessive body dive when braking. Body dive is body tilts down in front.

The suspensions system also works with the steering systems to help keep the wheels in correct Alignment and allows the front wheels to turn from side to side. Suspension system can be group to the two broad categories. Both can be found on car and truck. The group is independent and non independent. Independent suspension allows one wheel to move up and down with minimal effect on the other wheels. Non-independent suspension has both the right and left wheels attached to the same solid axle.

In the suspension system, there is having several major parts that has a many functions. The major parts is control arm, steering knuckle, ball joint, spring, short absorber or damper and control arm bushing. The function of control arm is movable lever that fastens the steering knuckle to the vehicle's body or frame. Steering knuckle is to provide a spindle or bearing support for the wheel hub, bearing and the wheel assembly.

Another part in suspension system is ball joint. Ball joint is movable connection that allows the control arm to move up and down while allowing the steering knuckle to swivel from side to side. The spring function is to support weight of the vehicle. It is a permit the control arm and wheel to move up and down. The part that connects with spring in suspension system is short absorber or damper. The function is to keeps the suspension from continuing the bounce after spring compression and extension. Last part is control arm bushing. Its function is to sleeve that allows the control arm to swing up and down on the frame.

Semi-active or active suspension is process when the suspension is externally controlled. It is the suspension is reacting to what are in effect when the signals will give. Semi-active suspensions include devices such as air springs and switchable shock absorbers, various self-levelling solutions, as well as systems like Hydropneumatic, Hydrolastic, and Hydragas suspensions. Semi-active also is a possible alternative way to fully active system to considerably improve suspension performances. The damping force of each suspension is obtained by modulating its damping factor according to opportune functions of the system state variables.

Fully active suspension systems use electronic monitoring of vehicle conditions, coupled with the means to impact vehicle suspension and behavior in real time to directly control the motion of the car.

1.2 OBJECTIVE

The objectives of this report are:

i. To create a mathematical model of racing car suspension system.
ii. To develop a suitable controller to improve vehicle ride handling.
iii. To compare the performance of semi-active suspension system with the passive system using the Matlab Simulink.

1.3 SCOPE

The scopes of this report are:

i. The simulation of race car suspension is performed in Matlab Simulink software.

ii. Developing a 7 DOF mathematical modeling ride based on vehicle model.

iii. The parameters of race car suspension are taken from the available rally car suspension system (*Subaru Impreza Group N Rally Car*).

1.4 PROBLEM STATEMENT

The behaviour of vehicle motion to the hard braking, cornering and others road condition will affect the vehicle handling and stability of the vehicle. The safety is an also main issue for this behaviour of vehicle motion. Actually, the racing car is an experimental to the vehicle component such as example the engine, body chassis, tyre and so on.

In the passive suspension system, the most issues are lack of attitude of the vehicle body especially in stability and performance (E. Guglielmino, T. Sireteanu, C. W. Stammers, G. Ghita, M. Giuclea, 2008). This behaviour will be taken to analysis to compare with the semi active suspension system. A mathematical modelling based on vehicle model is build to represent the actual vehicle behaviour based on stability and performance.